Graduate Program Opportunities in High Performance Computing

This document describes a special graduate education program utilizing the strengths of a unique triad located in Dayton, Ohio. The triad consists of an extremely powerful supercomputing resource, the Aeronautical Systems Center Major Shared Resource Center (ASC MSRC); the Air Force Research Lab (AFRL), the new consolidated research arm of the US Air Force; and the Dayton Area Graduate Studies Institute (DAGSI), a consortium of Southern Ohio universities including the Air Force Institute of Technology, the University of Dayton and Wright State University. Students in this program will perform important Department of Defense research on world class computational platforms as well as collaborate with many of the top scientists in the country while earning fully accredited graduate degrees in science and engineering.

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Introduction

"...leveraging the state of the art as it moves into the state of the practice"
Anita K Jones
Director of Defense Research and Engineering
Department of Defense
(1993-1997)

Wright-Patterson Air Force Base (WPAFB), located in Dayton, Ohio, is recognized as the "Birthplace of Aviation", primarily because of the pioneering achievements of the Wright brothers. Since the U.S. War Department established the Aeronautical Division in 1907, the Division and its successor organization, Aeronautical Systems Center (ASC), have carried on the mission of exploiting leading-edge aeronautical technology for use in war fighting applications.

In keeping with this long tradition of technical superiority, the Department of Defense (DoD) High Performance Computing (HPC) Modernization Program has officially designated the Aeronautical Systems Center (ASC) at WPAFB as one of four major shared resource centers (MSRCs). Each MSRC provides state-of-the-art HPC resources for DoD scientists and engineers from the Army, Navy, Air Force, and the Defense Agencies. With over 50% of the Air Force's research & development community residing at Wright-Patterson AFB, the ASC MSRC is a critical and readily accessible resource for the advancement of air power.

A recent initiative combines the resources of the ASC MSRC with the Air Force Research laboratory (AFRL) and the Air Force Institute of Technology (AFIT) to create graduate HPC research opportunities to help solve current Air Force challenges. AFRL is the Air Force's new consolidated organization with laboratory complexes located nationwide, and AFIT is the graduate school of the Air Force with numerous strong technical programs.

AFRL's headquarters and its largest laboratory complex are both located at Wright Patterson Air Force Base. The laboratory complex, formally known as Wright Laboratories (WL), led the discovery, development and transition of aeronautical technologies to make the U.S. Air Force the best in the world. Continuing this leadership, AFRL supports and participates in numerous HPC-related shared research efforts. Strong relationships with local universities such as the University of Dayton, Wright State University, and AFIT make research collaboration agreements routine.

AFIT provides responsive DoD related graduate and professional continuing education, research and consulting programs. The strong engineering and science programs sustain many cooperative research alliances (such as the Dayton Area Graduate Studies Institute, a cooperative organization of Southwest Ohio universities). As a result, AFIT offers a wellspring of qualified graduates and students for AFRL's computational science and engineering research programs.

Graduate Program Objective

As part of the DoD HPC Modemization Program, a consolidated team of MSRC, AFRL and AFIT/DAGSI researchers have formally developed a combined research/academic initiative. The goal of the program is to define, promote, support and conduct graduate level research and education which leverages HPC resources to the maximum possible extent in support of critical DoD objectives. Research at the ASC MSRC is focused in the following computational technology areas (CTAs):

- •Computational Structural Mechanics (CSM)
- •Computational Fluid Dynaniics (CFD)
- •Computational Chemistry & Materials Science (CCMS)
- •Computational Electromagnetics& Acoustics (CEA)
- •Computational Electronics & Nano-electronics (CEN)

Academics include associated CTA courses integrated with high performance computing courses. In addition to these areas, AFIT also offers curriculums in the following CTA areas:

- •Forces Modeling and Simulation
- •Signal/Image Processing

as well as a fundamental HPC curriculum:

- •Computational Science/Engineering

A detailed description of each academic supported area and listings of associated contacts from AFIT/DAGSI, AFRL, and the MSRC are provided under separate sections later in this brochure. Also, expanded information is available on the world wide web. A suggested starting point is the AFIT homepage (*http://www.afit.af.mil/Schools/EN*).

By associating with these CTA programs, students will have an opportunity to work with some of the leading AF Scientists on a myriad of subjects. Some of the most exciting projects have been selected by a panel of internationally renowned scientists, acting as consultants to the DoD High Performance Computing Office, as DoD Challenge Problems. Challenge problems are allotted additional computational resources and offer students the chance to perform cutting edge research side-by-side with some of the nations top scientists.

Sample DoD Challenge Problems

DoD Challenge Problems are quite varied. Diverse application examples include large-scale fluid and particle movement, electromagnetic computation, digital signal processing, computational fluid dynamics (CFD), large-scale semiconductor design, aircraft and spacecraft design, modeling and analysis of environmental scientific data, climate modeling, quantum chromodynamics (QCD), and composite material processing as well as genome studies, virtual reality, discrete-event simulation and large-scale optimal search processes. The results of these investigations could have a direct bearing on the success of future US scientific and business activities, and also will likely have an enormous impact on future military capabilities.The following subsections outline some of the DoD Challenge Problems supported by the ASC MSRC last year.

New Materials Design

Dr. Ruth Pachter
Air Force Research Lab, Wright-Patterson AFB, OH

Description: New optical limiting materials with fast non-linear optical response over broad spectral bandwidths, self-assembled nano-structures for optical switching, and switchable light shutters, are critical for laser eye and sensor protection in the DoD. These materials are being designed using extensive HPC resources.

Porphyrin and phthalocyanine based materials are promising optical limiters with markedly changed properties due to solvent effects. Calculations of interactions with the effective-fragment potential method, where solvent molecules are placed around a solute to generate correctly the first salvation cell within the paralleled GAMESS ab initio framework, will constitute a first such grand challenge attempt of 10-30 gigaflop-years in modeling the behavior of a complex material in solution. Polymer dispersed (PD) liquid crystals (LC) are of interest for laser protection as switchable flight shutters. The size and shape of the droplets and the orientations of the director of the LC molecules play a significant role in determining the switching times and re-orientation field required by the PDLC device and are therefore of importance for its design. It is proposed to perform large scale material problems including all atomistic interactions of importance. These applications, combined with the innovative use of HPC through our CHSSI efforts for the ab initio GAMESS and molecular dynamics codes, have the potential for significant progress in materials design that will affect the DoD laser protection capability, as well as the scientific community as a whole.

B-1B Radar Cross-Section Prediction

Dr. Joseph J.S. Shang
Air Force Research Lab, Wright-Patterson AFB, OH

Description: The proposed DoD Challenge Project describes modeling and simulation tool development through a unique combination of innovative high resolution numerical algorithm and scalable parallel computing. To assess the true potential of a computational electromagnetics simulation, three-dimensional, time-dependent Maxwell equations on non-unique memory access processors will be solved. A new approach for huge volumes of data and data flow will also be tested for more effective and wider range of applications. The computed results of the scaled B-1B aircraft are designed to support directly the B-1B Defensive System Upgrade Program (DSUP) of the AF Operational Test and Evaluation Center. The high accuracy requirement in different phases of engagement imposes critical validation criterion for future model and simulation applications and offers technical challenges for computational electromagnetics.

Simulation of Explosions for Counter Proliferation and Counter-Terrorism

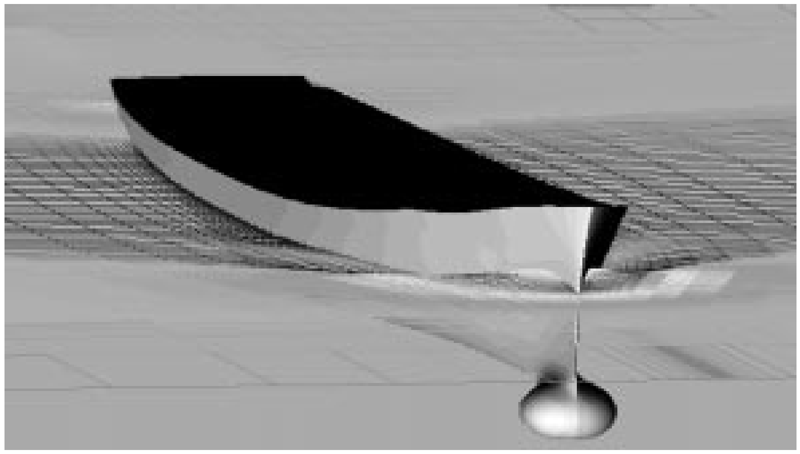
Dr. John Bell and Dr Phillip Colella
Lawrence Berkeley National Laboratory, Berkeley, CA

Description: We are developing end-to-end simulation capabilities for modeling explosion effects related to Counter-Proliferation and Counter-Terrorism scenarios in support of the Defense Special Weapons Agency (DSWA). These problems include explosions in buried chamber systems for military applications and explosions in or near buildings for civilian applications.

Simulations include characterization of the sources due to such explosions and subsequent local dispersion, and large-scale transport of contaminants, including the effects of terrain, atmospheric stratification, and local meteorology. Our approach, which is based on high-resolution adaptive numerical methods (developed under DSWA's Advanced Computational Methods Program), is designed to provide a capability of performing detailed first-principles calculations of such turbulent explosion fields. Results of such analysis provides vital input to military strategy for Counter-Proliferation measures, aid forensic investigations of terrorist bombing incidents, and suggest methods of protecting US troops abroad and US civilians at home.

Time-Domain Computational Ship Hydrodynamics

Dr. Edwin P. Rood, Team Leader
Office of Naval Research, Arlington, VA



The DoD Challenge Project Time-Domain Computational Ship Hydrodynamics is a team effort to apply emerging numerical methods to the prediction of complex hydrodynamics for naval combatants. The team consists of specialists from several organizations, each of whom has a particular computational approach to modeling the ship hydrodynamics. The approaches are complementary, and taken together model the important features of the hydrodynamics. Hence the Challenge Project is characterized as a direct assault on the ship hydrodynamics problem with a suite of software. The Challenge team is lead by an ONR scientist who, with specialized knowledge of the Navy needs and the numerical science relevance, facilitates the cohesiveness of the project.

Academic Programs*

Doctoral Programs

The Doctor of Philosophy (Ph.D.) is a research degree. It represents a focused effort consisting of mastery of a specialized field and a demonstrated ability to do independent research leading to a significant and original contribution to the body of knowledge. A person upon whom the Ph.D. has been conferred is considered an expert in their research specialty with broad competency in the key areas of their chosen technical discipline.

The Ph.D. coursework consists of a minimum of 48 quarter hours study beyond the MS degree. The coursework is divided into the Specialty Area (minimum 24 hrs.), the Minor Area (minimum 12 hrs.), and the Math Requirement (three approved courses). These are general requirements for all PhD candidates (consult AFIT/EN PhD Brochure for details). Students associated with the High Performance Computing (HPC) program will also orient their programs with an HPC interdisciplinary emphasis. Also, a dual degree option is available for HPC students which can result in a concurrent awarding of a computer science masters with computational emphasis and a PhD in the students chosen CTA discipline.

* These descriptions are based on AFIT programs. Consult other DAGSI schools for their guidelines. Regardless of school application, each student will establish an individual program through consultation with their CTA triad.

Specialty Area

The Specialty Area consists of courses which directly support the research goals of the student. These courses are generally chosen from established course sequences. The Computational Technology Area (CTA) related sequences are listed in the next section of this brochure. Your advisor will help direct your selection.

Minor Area - HPC Computation Courses

The Minor Area is a related topic area designed to support and complement the major area. The series of HPC computation courses offered at AFIT should be taken to fill this requirement. The High Performance Computing courses introduce students to the tools and techniques available for use on the MSRC supercomputing platforms. After an introduction in Parallel and Distributed Processing Algorithms, case studies geared toward the students' specialty areas will be addressed in Advanced Parallel and Distributed Computation. A new scientific visualization course completes the minor by providing insight in the selection of appropriate techniques when utilizing the MSRC advanced visualization tools.

Math Requirement

The AFIT Ph.D. Mathematics Requirement is outlined in the Doctoral Council Policy Letter "Mathematics Examination". Students are encouraged to take three mathematics courses, but testing is available as an alternative for those with strong backgrounds in mathematics. The specific course options to fulfill this requirement are determined by each department, but all HPC students should orient their studies toward discrete mathematics and numerical methods

.Masters Programs

All MS Programs require the student complete 48 quarter hours of graduate coursework and include a thesis. The specifics of masters programs vary depending on the related technical discipline. In general, however, they all require demonstrated abilities in a set of core courses as well as the pursuit of advanced knowledge through course sequences. Prerequisites are also reviewed to insure a student has the proper background for their chosen discipline. Note that these interdisciplinary curriculums are individually administered by the appropriate AFIT Graduate School of Engineering department as indicated. Thus their academic program guide should be consulted for specific details.

Prerequisites

The prerequisites will typically be listed by subject, but an accredited related degree would also fulfill this requirement. Those seeking a masters in a field not directly related to their undergraduate specialty may be required to strengthen their backgrounds during initial coursework. The extent of this requirement will be determined on an individual basis with the assistance of an academic advisor.

Core

The core requirements consist of a basic set of advanced fundamentals which directly support the students chosen field of study. Some of the core requirements can be waived by demonstrated capabilities (as indicated in prior transcripts). Again, the extent of the core requirements will be determined on an individual basis.

Math Requirements

As in the PhD program, the specific course options to fulfill this requirement are determined by each department, but all HPC students should orient their studies toward discrete mathematics and numerical methods where possible.

Major Sequences

Major sequences are related courses which build upon each other and directly support the achievement of mastery in a specified field. Sequences related to High Performance Computing (HPC) are listed by Computational Technology Area (CTA) in the next section of this brochure. Typically a student will be required to complete two sequences. HPC students should plan on completing the series of HPC computational courses (see Doctoral Program Minor Area for a description) in addition to a set related to their chosen field of study. This combination of sequences will provide the best preparation for pursuing the related MSRC research (and will result in the designation of a specialization in HPC on the student's transcript).

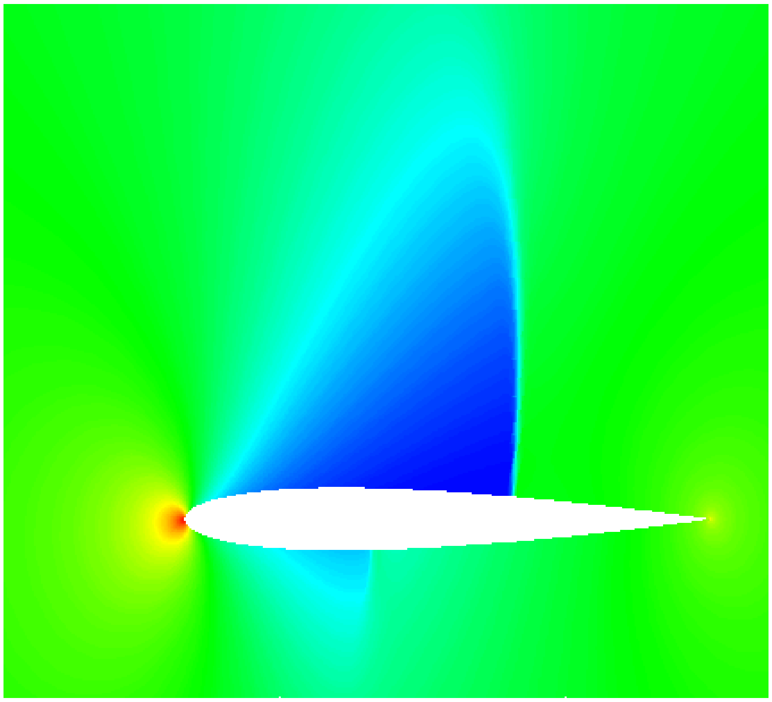
Electives

Students may tailor their programs and support their thesis research with elective courses. The list of approved electives is quite varied and is generated from the wide spectrum of specialties available at AFIT. The selection of such courses will be facilitated by academic advisors.

Computational Technology Areas*

Computational Fluid Dynamics (CFD)

The Computational Fluid Dynamics CTA covers High Performance Computation whose goal is the accurate numerical solution of the equations describing fluid and gas motion and the related use of digital computers in fluid-dynamics research. CFD is used for basic studies of fluid dynamics, for engineering design of complex flow configurations, and for predicting the interactions of chemistry with fluid flow for combustion and propulsion. It is also used to interpret and analyze experimental data and to extrapolate into regimes that are inaccessible or too costly to study. Work in the CFD CTA encompasses all velocity flow regimes and scales of interest to the DoD. Incompressible flows are slow, e.g., governing the dynamics of submarines, slow airplanes, pipe flows, and air circulation. Compressible flows are important at higher speeds, e.g., controlling the behavior of transonic and supersonic planes, missiles, and projectiles.



Fluid dynamics itself displays some very complex physics, such as boundary-layer flows, transition to turbulence, and turbulence dynamics, that require continued scientific research. CFD also must incorporate complex additional physics to deal with many real world problems. This may entail additional force fields, coupling to surface atomic physics and microphysics, changes of phase, changes of chemical composition, and interactions among multiple phases in heterogeneous flows. Examples of these physical complexities include Direct Simulation Monte Carlo and plasma simulation for atmospheric re-entry,

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microelectro-mechanical systems (MEMS), and materials processing, and magneto hydrodynamics (MHD) for advanced power systems and weapons effects. CFD has no restrictions on the geometry and includes motion and deformation of solid boundaries defining the flow.

Associated courses include:

Core Courses in CFD:

AERO 520 Viscous Flow
AERO 536 High-Speed Aero
AERO 542 Computational Modeling for Aero
AERO 751 Finite-Difference Methods for Fluid Mech

Math:

MATH 511 Methods of Appl Math I
MATH 513 Methods of Appl Math II
MATH 621 Linear Algebra

HPC Courses:

CSCE 656 Parallel and Distributed Processing Algorithms
CSCE 790 Advanced Parallel and Distributed Computation
CSCE 657 Scientific Visualization in High Performance Computing

Sequence I: Computational Algorithms

Sequence provides theoretical foundations for a wide range of finite-difference and finite-volume algorithms. Students apply algorithms to a variety of flowfield situations in 2-D and 3-D that serve as critical evaluations of concepts developed in class.

AERO 752 Computational Aerodynamics
AERO 753 Adv. Comp. AERO
AERO xxx Unstructured Methodologies

Sequence II: Turbulence Modeling

This sequence provides an introduction to turbulence modeling in CFD. AERO 827 introduces the physics and mathematics of turbulence, develops zero-, one- and two-equation turbulence models, and tests these models using computer applications. Higher-order methods are also described. The principles of large-eddy simulation (LES) are examined in the last class; students are given the opportunity to study model problems with LES at the MSRC.

AERO 752 Comp. Aero
AERO 827 Turbulence
AERO xxx Large-Eddy Simulation

Sequence III: Grid Generation

Sequence III provides a systematic review of theoretical and practical concepts in grid generation for CFD analysis. Algebraic, elliptic, hyperbolic and parabolic techniques are developed, implemented and tested for a number of practical configurations. Transfinite interpolation and NURB technologies are described. In Grid Gen II, advanced concepts for unstructured grids, such as Delaunay triangulation, are provided. Extensive use will be made of software tools available at the MSRC.

AERO xxx Grid Gen I
AERO 752 Comp. Aero.
AERO xxx Grid Gen II

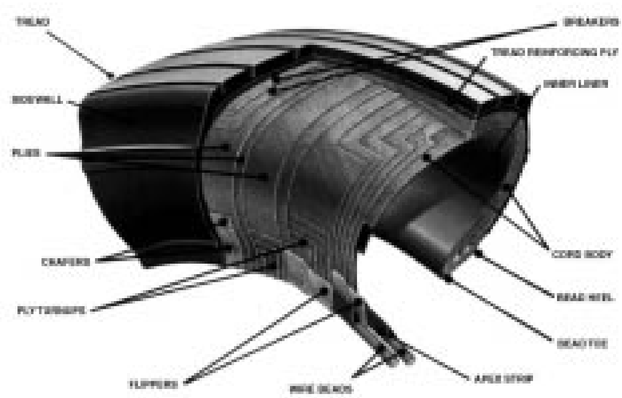
Sequence IV: Computational Aeroelasticity

This sequence provides an overview of the field of computational aeroelasticity, with emphasis given to the analysis of full configurations in either subsonic or supersonic flow. Theoretical concepts will be introduced in MECH 662, and expanded upon in AERO xxx — topics include strip theory, the doublet-lattice method, constant-pressure method, harmonic gradient-method, K method, PK method, and the QR algorithm. A generic fighter configuration will be examined for its flutter characteristics using NASTRAN at the MSRC.

MECH 662 Introduction to Aeroelasticity
MECH xxx Finite Element Analysis with NASTRAN [advanced Mech 481]
AERO xxx Modern Flutter Analysis w/ NASTRAN

Computational Structural Mechanics (CSM)

Computational Structural Mechanics (CSM) covers the high resolution multi-dimensional modeling of materials and structures subjected to a broad range of loading conditions including static, dynamic, and impulsive. CSM encompasses a wide range of engineering problems in solid mechanics such as linear elastic stress analysis, material or structural response to time dependent loading, large deformations, shock wave propagation, plasticity, frequency response, and nonlinear material behavior. High performance computing for CSM addresses the accurate numerical solution of the conservation equations, equations of motion, and constitutive relationships to model simple or complex geometries and material properties, subject to external boundary conditions and loads. CSM is used for basic studies in continuum mechanics, stress analysis for engineering design studies, and predicting structural and material response to impulsive loads. DoD application areas include conventional underwater explosion and ship response, structural acoustics, coupled field problems, space debris, propulsion systems, structural analysis, total weapon simulation, weapon systems' lethality/survivability (e.g., aircraft, ships, submarines, tanks), theater missile defense lethality analyses, optimization techniques, and real-time, large-scale soldier and hardware in-the-loop ground vehicle dynamic simulation.



Associated courses include:

Core Courses in CSM:

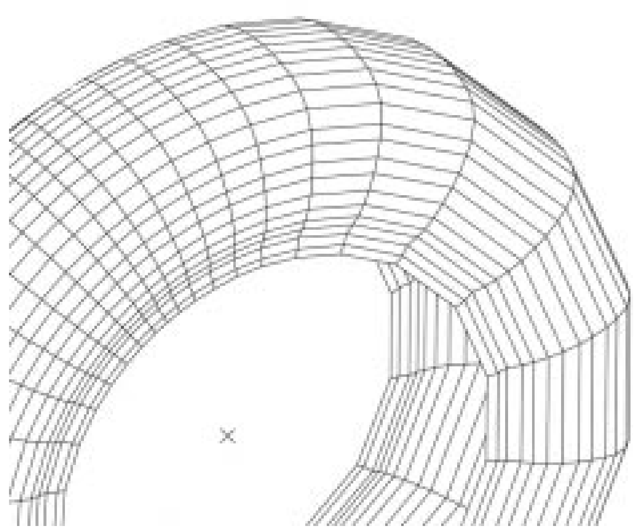
MECH 500 Fundamentals of Solid Mechanics
MECH 515 Theory of Vibrations
MECH 600 Elasticity

Math:

MATH 621 Linear Algebra
MATH 674 Numerical Analysis

HPC Courses:

CSCE 656 Parallel and Distributed Processing Algorithms



gdp@asc.hpc.mil

CSCE 790 Advanced Parallel and Distributed Computation
CSCE 657 Scientific Visualization in High Performance Computing

CSM Sequences:

Either of the two CSM sequences may be taken. In both sequences the characteristics of nonlinear mechanics will be explored including dynamic and static relations. The first two courses in each are identical. The third course differentiates the sequences as indicated.

CSM Sequence I:

MECH 642 Finite Element Methods for Structural Analysis I
MECH 644 Finite Element Methods for Analysis II
MECH 741 Advanced Topics in Mechanics of Structural Materials

CSM Sequence II:

MECH 642 Finite Element Methods for Structural Analysis I
MECH 644 Finite Element Methods for Structural Analysis II
MECH xxx Structure-Fluid Interaction

Computational Chemistry and Materials Science (CCM)

The Computational Chemistry and Materials Science CTA covers the computational research tools used to predict basic properties of new chemical species and materials which may be difficult or impossible to obtain experimentally such as: molecular geometries and energies, spectroscopic constants, intermolecular forces, reaction potential energy surfaces, and mechanical properties. Within DoD, quantum chemistry and molecular dynamics methods are used to design new chemical systems for fuels, lubricants, explosive, rocket propellants, catalysts, and chemical defense agents. Also within DoD, solid state modeling techniques are employed in the development of new high-performance materials for electronics, optical computing, advanced sensors, aircraft engines and structures, semiconductor lasers, laser protection systems, advanced rocket engines components, and biomedical applications.
A student wishing to pursue this CTA should have a background including physical chemistry, introductory quantum mechanics, differential equations, and, at a minimum, elementary programming skills. Shortfalls, however, can be filled with initial AFIT courses.

Associated courses include:

Core Courses in CCM:

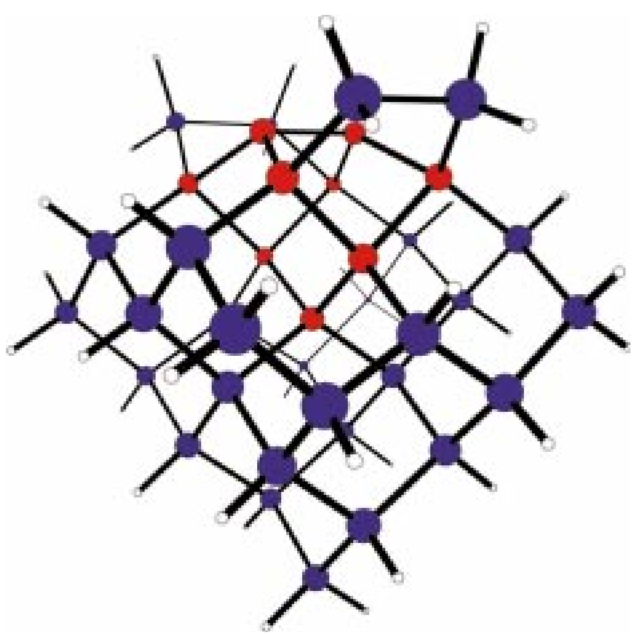
PHYS 600 Dynamics
PHYS 635 Thermal Physics
PHYS 655 Quantum Mechanics I

Math:

MATH 508 Applied Numerical Methods

HPC Courses:

CSCE 586 Advanced Information Structures
CSCE 656 Parallel and Distributed Processing Algorithms
CSCE 790 Advanced Parallel and Distributed Computation
CSCE 657 Scientific Visualization in High Performance Computing



Computational Chemistry and Materials Sequence:

This sequence includes a study of the chemistry of materials and processes important in current and future aerospace manufacturing and maintenance, an introduction to the electronic behavior of molecules and solid state materials, and a laboratory course emphasizing the methods used in computational chemistry.

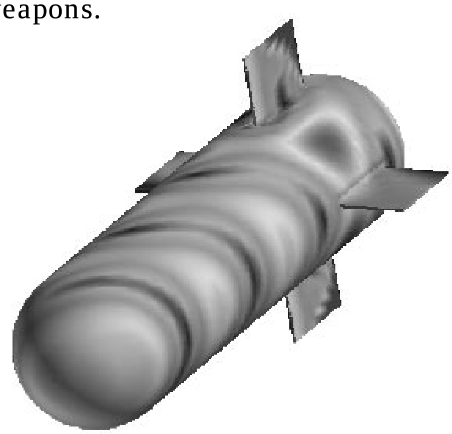
CHEM 620 Materials Chemistry
CHEM 662 Electronic Properties of Molecules and Solids
CHEM 750 Computational Chemistry and Materials Science Laboratory

Computational Electromagnetics and Acoustics (CEA)

The Computational Electromagnetics area covers the high resolution multi-dimensional solutions of Maxwell's equations. DoD applications include calculating the electromagnetic fields about antenna arrays, the electromagnetic signatures of tactical ground, air, sea and space vehicles, the electromagnetic performance and design factors for EM gun technology, the electromagnetic signature of buried munitions, high power microwave performance, as well as the interdisciplinary applications in magnetohydrodynamics and laser systems.

The Computational Acoustics area covers the high-resolution multi-dimensional solutions of the acoustic wave equations in solids, fluids, and gases. DoD applications include the modeling of acoustic fields for surveillance and communication, seismic fields for mine detection, and the acoustic shock waves of explosions for anti-personnel weapons.

Associated courses include:



Core Courses in Electromagnetics:

EENG 524 Electromagnetis Waves I
EENG 576 Microwaves
EENG 625 Antennas I

Core Courses in Acoustics

EENG 5xx Acoustics I
EENG 6xx Acoustics II

Math (choice of two):

MATH 504 Differential Equations
MATH 506 Fourier Series and Boundary Value Problems
MATH 521 Applied Linear Algebra
STAT 586 Probability and Random Variations

HPC Courses:

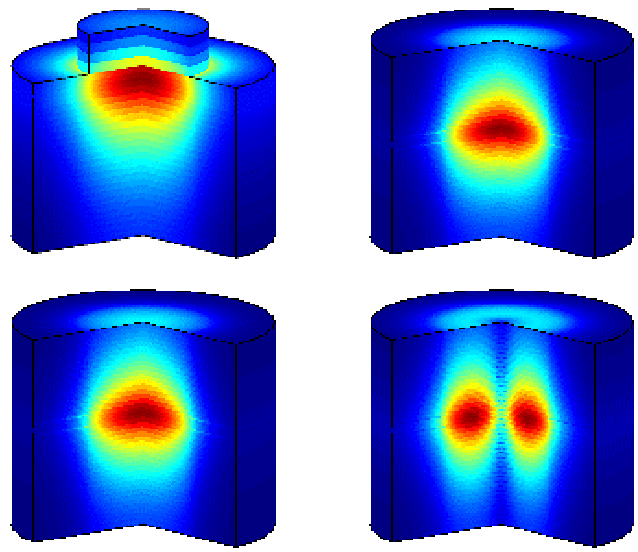
CSCE 656 Parallel and Distributed Processing Algorithms
CSCE 790 Advanced Parallel and DistributedComputation
CSCE 657 Scientific Visualization in High Performance Computing

CEA Sequence:

Each CEA student will construct his sequence from the list of courses below.

EENG 535 Radar Systems
EENG 627 Radar Cross Section
EENG 630 Electromagnetic Wave Scattering
EENG 631 Advanced Antennas
EENG 725 Advanced Electromagnetic Theory I
EENG 726 Advanced Electromagnetic Theory II
EENG 727 Advanced Electromagnetic Theory III

Computational Electronics and Nano-electronics (CEN)



The Computational Electronics and Nanoelectronics CTA covers High Performance Computation for the accurate design and efficient numerical modeling and simulation of complex electronic devices, integrated circuits, and photonic systems. Generally, the goal of research in this area is to lower the cost and/or enable improved performance of DoD electronics through a variety of CAD/ CAE, predictive modeling, and simulation techniques applied to subjects such as (1) linear and nonlinear analysis, (2) time- and frequency-domain modeling, (3) physics-based transport, diffusion, and tunneling in semiconductors, (4) quantum transport in 'designer' electronic materials, (5) electromechanics and (6) structural analysis of microelectronics including effects of electrostatics, magnetostatics, acceleration, vibration, and mass-loading.
Areas of investigation of interest to DoD include (1) analog/digital high-frequency circuit and device simulation and optimization, (2) modeling and simulation of micro-electromechanical devices and micro-resonators, (3) computational EM/numerical methods for active and passive microwave and millimeter-wave circuits and structures, (4) analysis of coupled nonlinear devices, (4) noise and stochastic modeling, (5) electronic/ photonic interconnect and packaging analysis, (6) neural networks and formal design methods, (7) statistical analysis, design, and synthesis, (8) design-for-test, and (9) fault modeling.

Associated courses include:

Core Courses in CEN:

PHYS 570 Physics of Solid State Devices
PHYS 671 Selected Topics in Solid State Physics
EENG 675 Semiconductor Device Technology

Math:

MATH 621 Linear Algebra
MATH 674 Numerical Analysis

HPC Courses:

CSCE 656 Parallel and Distributed Processing Algorithms
CSCE 790 Advanced Parallel and Distributed Computation
CSCE 657 Scientific Visualization in High Performance Computing

CEN Sequence:

EENG 676 Microwave Electronic Devices
EENG 717 Topics in Electronic Device Technology
OENG 775 Photonics

Forces Modeling and Simulation (FMS)

The Forces Modeling and Simulation/C^4I CTA covers (1) the use of command, control, communications, computers, and intelligence (C^4I) systems to manage a battle space; (2) the use of large-scale simulations of complex military engagements to facilitate mission rehearsal/ training, mission planning, and post-mission analysis; (3) the use of collaborative planning to support real-time decision making; and (4) the use of digital library technology for support of FMS/C^4I research and development activities.

Across the DoD, the variety of applications is large - with remarkable diversity of purpose, scope, resolution, emphasis, and time of effect. Common technology threads include object-oriented, distributed parallel, highly compute and communications intensive, and time sensitive attributes. Applications exist in design, development, test, evaluation, deployed systems, and training systems.

Associated courses include:

Core Courses in Operations Research:

OPER 540 Probabilistic Operations Research
OPER 561 Object Oriented Military Systems Simulation
OPER 610 Linear Programming and Network Flows
OPER 671 Joint Combat Modeling

Math:

MATH 501 Mathematics for the Operational Sciences I
MATH 502 Mathematics for the Operational Sciences II
STAT 537 Introduction to Statistics
STAT 696 Applied General Linear Models

HPC Courses:

CSCE 656 Parallel and Distributed Processing Algorithms
CSCE 790 Advanced Parallel and Distributed Computation
CSCE 657 Scientific Visualization in High Performance Computing

Operational Analysis Program:

This program prepares candidates to conduct analysis of military forces. The program provides students with a strong foundation in quantitative analysis methods. Areas of study include probability, statistics, mathematics, operations research, modeling and simulation, and joint combat modeling. Based on student interests, students take courses in a Modeling and Simulation (M&S) Sequence or in an Operational Effectiveness Sequence. Subjects in the M&S Sequence include computer databases, computer communication networks, and advanced joint combat modeling or joint mobility modeling. Subjects in the Operational Effectiveness Sequence include conventional weapons effects or nuclear weapons effects, technology, and non-proliferation; and communications, command and control and the principles of electronic warfare. Each of these tracks can be tailored to incorporate the latest approaches in High Performance Computing. A 12-hour thesis effort provides the high performance computing student a “hands on experience” in applying the latest technology to a real world operational problem.

Modeling and Simulation Sequence:

CSCE 654 Computer Communication Networks
CSCE 545 Database Methods and Paradigmsfor M & S
OPER 672 Joint Combat Modeling II
OPER 674 Joint Mobility Modeling

Operational Effectiveness Sequence:

EENG 574 Comm, Command and Control, and Principles of Electronic Warfare
OPER 632 Cost Analysis for System Design
NENG 597 Nuclear Weapons Effects,Technology, and Non-Proliferation
SENG 564 Conventional Weapons Effects

Operations Research Program:

The purpose of the Operations Research program is to educate students in the theory and practice of operations research, with emphasis on the application of quantitative analysis techniques to defense decision-making. Specific topics of study include mathematical modeling, simulation, statistical analysis, and optimization The program includes a three-course sequence in one of the specialty areas described below. Other courses may be substituted with the approval of the GOR Program Director. A 12-hour thesis effort provides the high performance computing student a "hands on experience" in applying the latest technology to a real world operational problem. The program is continuously reviewed by the users of program graduates, including the Air Force Studies and Analysis Agency, The Air Force Operational Test and Evaluation Center, and Major Command analysis groups. Sequences are composed of three selections of courses in one of the following specialty areas (see the AFIT Operational Sciences Brochure for details).

Deterministic Operations Research:

Probabilistic Operations Research:

Modeling & Simulation:

Applied Statistics:

Operational Modeling:

Signal/Image Processing (SIP)

The Signal/Image Processing CTA covers the extraction of useful information from sensor outputs in real time. DoD applications include surveillance, reconnaissance, intelligence, communications, avionics, smart munitions, and electronic warfare. Sensor types include sonar, radar, visible and infrared imagers, and signal intelligence (SIGINT) and navigation assets. Typical signal processing functions include detecting, tracking classifying, and recognizing targets in the midst of noise and jamming. Image processing functions include the generation of high-resolution low-noise imagery and the compression of imagery for communications and storage.
The CTA emphasizes research, evaluation, and test of the latest signal processing concepts directed toward these embedded systems. Usually such processors are aboard deployable military systems and hence require ruggedized packaging and minimum size, weight, and power. System affordability is expected to improve an order of magnitude through the development of scalable codes running on flexible HPC systems. This will enable the traditional expensive military-unique 'black boxes' required to implement high-speed signal/image processing to be replaced by COTS HPC-based equipment. Prerequisites include probability theory and basic applied linear algebra.

Associated courses include:

Core Courses in SIP:

EENG 580 Signal Processing Principles
EENG 665 Random Signal and System Analysis

Math:

MATH 621 Linear Algebra
MATH xxx Numerical Linear Algebra

HPC Courses:

CSCE 656 Parallel and Distributed Processing Algorithms
CSCE 790 Advanced Parallel and Distributed Computation
CSCE 657 Scientific Visualization in High Performance Computing

SIP Sequence:

EENG 680 Multidimensional Signal and Image Processing
EENG 681 Multirate Systems, Wavelets, and Image Compression
EENG 682 Least Square Estimation with Signal Processing Applications

Computational Science and Engineering (HPC Focus)

The Computational Science and Computational Engineering curriculum provides a course of study that embodies the interdisciplinary area of computational science and computational engineering at the graduate level (MS and PhD). Emphasis focuses on developing or extending the knowledge of advanced algorithm and data structure design, object-oriented design, computational theory, scalable supercomputer architecture and software engineering from the disciplines of computer science and computer engineering. Also, extensive knowledge from a selected scientific or engineering field is integrated within each individual curriculum. Student research emphasizes a particular scalable supercomputer application related to their multidisciplinary education and experience. The academic focus here is more in the computer science or computer engineering arena with integrated HPC courses and CTA interdisciplinary courses. The previous CTA emphasis has more of a scientific or engineering focus by construction.

Associated courses include:

Core Courses in CSCE:

CSCE 531 Discrete Structures
CSCE 532 Automata and Formal Language Theory
CSCE 586 Design and Analysis of Algorithms
CSCE 631 Machines, Languages, and Logic
CSCE 686 Advanced Algorithm Design
CSCE 689 Advanced Operating Systems

Math:

MATH 508 Applied Numerical Methods
MATH 583 Probability and Statistics

HPC Courses:

CSCE 656 Parallel and Distributed Processing Algorithms
CSCE 790 Advanced Parallel and Distributed Computation
CSCE 657 Scientific Visualization in High Performance Computing

Possible Sequences

Computer Architecture	Computer Networks
Computer Graphics	Database
Computer Engineering	Software Engineering

HPC Applications Sequence:

The student will select, in concert with a specific CTA advisor, at least three application courses. These courses should provide interdisciplinary knowledge within the selected CTA scientific or engineering discipline. To find specific graduate course candidates consult the CTA course listings.

Facilities

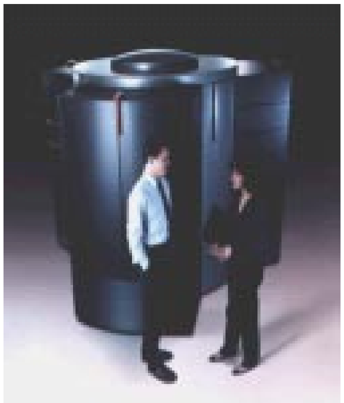
Major Shared Resource Center (MSRC)

Hardware

As a result of the award on May 1, 1996 to Nichols Research Corporation of Huntsville, Alabama, the ASC MSRC has been enhanced with the following equipment: Cray C90, SGI

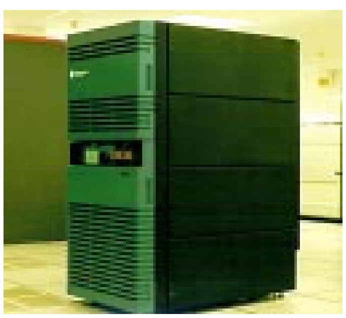
Power Challenge, IBM SP, Cray J90 and the SGI/Cray Origin2000. Brief descriptions are listed below. For details on continuing up grades consult the ASC MSRC website at:

<http://www.asc.hpc.mil/>



CRAY C916. The Cray C916, developed by Cray Research, Inc., features 16 Processors, 8 gigabytes of memory, and 200 gigabytes of disk space. This computer system provides vector parallel capability for vector-optimized, and large shared memory codes.

IBM SP. The IBM SP initially consisted of 80 Processor Elements (PEs), 68 gigabytes of memory, and 990 gigabytes of disk space. The SP architecture is based on the IBM RS/6000 Processor. The SP provides message passing parallel capability and additional parallel processing resources. Under the increased scope of Performance level 2 the IBM SP was upgraded to 256 nodes with 244 gigabytes of disk memory.



SGI POWER CHALLENGE. The SGI Power Challenge, produced by Silicon Graphics Incorporated, is configured with 16 processors, 8 gigabytes of memory and 200 gigabytes of disk space. This system will support the shared memory and message passing programming models.

SGI/CRAY Origin2000 The SGI/Cray Origin2000 is configured with a revolutionary new architecture called Scalable Shared-memory Multiprocessing. This new High Performance Computer has 224 R10000 Processors with 112 gigabytes Distributive Shared Memory. The Origin2000 is designed to run a full spectrum of third-party supercomputing applications.

CRAY J916/2512. The Cray J916 is configured with 252 gigabytes of disk space and will serve as the “front end” to the Storage Tek 9310, a product of Storage Technology Incorporated. It will be used to provide proven, reliable storage management. This system uses state-of-the-art robotics and technology for archival purposes. Initially, the unit has a 30 terabyte tape capacity.

Operating Systems and Software

Under the ASC MSRC contract award, additional software and the latest versions of much of the existing software will be installed. Software has been categorized into two groups, Computational Technology Area (CTA) related software and visualization software. Major CTA software packages proposed for the initial configuration are: ABAQUS, ADINA, AMBER, AMSOL , ANSYS, ASTROS, CHARMM, CTH/PCTH, DISCOVER, DMOL, DYNA3D, EASY5, ENSIGHT, EXPRESS, FAST, FNL (IMSL), GAMESS, GRIDGEN, GASP, GAUSSIAN, HPF, INSIGHT, LS-DYNA3D, MACH2/MACH3, MAPLE, MOPAC, MPI, MSC/DYTRAN, MSC/NASTRAN, MSC/PATRAN, NCAR GRAPHICS, PVM, SLATEC, TEX, VAST, and VGRID.

Major visualization software packages are: AVS, DYNAMATION, EAGLEVIEW, FIELDVIEW, FRAMEMAKER, GNUPLOT, IDEAS CORE MASTER MODELER, IDEAS SIMULATION SET, IMAGE VISION, IMTOOLS, INVENTOR, KHOROS, LIGHTWAVE, MAPLE, MATHEMATICA, MATLAB, PERFORMER, PRO/ENGINEER, PV-WAVE, PV-WAVE GTGRD, RADIANCE, SPICE2/SPICE3, TECPLOT, UIM/X, VISUALIZER. Information regarding which software is available on specific platforms can be found on the ASC MSRC website ***(http://asc.hpc.mil/).***

User Support/Training

A major effort was launched by the Ohio Supercomputing Center (OSC) to incorporate a Programming, Environment and Training (PET) program to integrate digital libraries & software tools to aid DoD Scientists and Engineers to use commercially off the shelf applications. The ASC MSRC provides a robust collaborative effort headed by a team of academic professionals at the Doctorate level to transfer the latest technology to the DoD researcher. These CTA trackers conduct classes, provide workshops, and construct distance learning materials to aid in the technology transfer.

Air Force Institute of Technology

Students and faculty at the Air Force Institute of Technology have easy access to the MSRC resources through a fully networked system of workstations and personal computers located throughout the AFIT facilities. Several department level computer centers as well as a workstation center supporting all of AFIT are utilized for class and research. The AFIT system is fully supported by a professional computer support staff and also allows easy access to the internet and the world wide web.

Financial Issues

Financial support is available for both AFIT graduate and post-doctoral research. In addition to research funding, scholarships may be obtained through the Dayton Area Graduate Studies Institute (DAGSI). The following positions are available for DAGSI students who declare AFIT as their home school. Funding for students associated with other DAGSI schools will be developed on an individual basis through the triad organization. For information and enrollment asstance, contact the PET Program Office at (937) 255-5075, ext. 225 or <gdp@asc.hpc.mil>.

Research Positions

Individuals are classified in one of the following two categories:

Research Assistant: An MS or PhD student actively pursuing a degree at AFIT who is also hired as a part time, temporary Air Force employee to perform work on funded research projects. Pay for Research Assistants is provided entirely by research money obtained by the AFIT faculty supervisor. For purposes of determining effective pay grades, Research Assistants will be Instructors in the civilian Faculty Pay Plan. Research Assistants are hired on a renewable one year term basis, and must be US citizens.

Research Associate: A post doctoral researcher hired as a full time temporary Air Force employee to work on funded research. In rare instances, it may be desirable to hire a Research Associate who is pursuing a PhD, but is in "all but dissertation" (ABD) status. Pay for Research Associates is provided entirely by research money obtained by the AFIT faculty supervisor. For purposes of determining effective pay grades, Research Associates will be Assistant Professors in the civilian Faculty Pay Plan. Research Associates are hired on a renewable one year term basis, and must be US citizens.

Implementation Details for AFIT Research Assistants

1. One or more AFIT faculty are expected to be heavily involved in the research conducted by every Research Assistant.

2. Research Assistants must be actively pursuing degrees at AFIT. This normally constitutes taking from 8 to 12 quarter credit hours of course work per quarter at AFIT or a DAGSI partner school for at least three of the four academic quarters per year. AFIT must be the home school for Research Assistants.

3. Research Assistants will be paid up to a half-time rate (i.e., 40 hours per two week pay period) when they are actively working on their project. The AFIT faculty supervisor is responsible for evaluating the time and effort Research Assistants devote to their assigned research task, and making sure that time cards reflect a fair and equitable level of effort by the student.

4. Research Assistants will be paid from the civilian Faculty Pay Plan as Instructors. There are three possible steps:

   MS: Defined as a student pursuing an AFIT master's degree. A student pursuing a master's degree will be allowed to work no more than half time. The hourly rate of pay will be that of step four on the civilian Faculty Pay Plan. (This corresponds to a rate of $15.77 per hour, or $16,403.79 per year if the student charges the full 1040 hours available to a half-time employee.)

   PhD-1: Defined as a student who has completed a master's and is pursuing a PhD degree at AFIT, but who has yet to be admitted to candidacy. A PhD-1 student will be allowed to work no more than half time. The rate of pay will be that of step seven on the civilian Faculty Pay Plan. (This corresponds to a rate of $17.26 per hour, or $17,953.58 per year if the student charges the full 1040 hours available to a half-time employee.)

   PhD-2: Defined as a student who has been admitted to candidacy for a PhD degree at AFIT. A PhD-2 student will be allowed to work no more than half time. The hourly rate of pay will be that of step eleven on the civilian Faculty Pay Plan. (This corresponds to a rate of $19.25 per hour, or $20,020.62 per year if the student charges the full 1040 hours available to a half-time employee.)

Implementation Details for AFIT Research Associates

1. One or more AFIT faculty are expected to be heavily involved in every research project conducted by a Research Associate.

2. Research Associates will be paid at the full time rate from the civilian Faculty Pay Plan as Assistant Professors. Salary will be negotiated between the faculty supervisor and the prospective Research Associate.

3. Research Associates who are in All-But-Degree (ABD) status may be hired at a half time rate from the Faculty Pay Plan Assistant Professor pay scale. This half-time status can be converted to full time status upon completion of the PhD degree requirements.

For further details concerning either research position, contact the appropriate AFIT/EN department head, the AFIT CTA leader, or the AFIT homepage on the world wide web <***http://www.afit.af.mil/Schools/EN***>.

Scholarships

Full-tuition scholarships will be awarded to qualifying individuals through the Dayton Area Graduate Studies Institute (DAGSI). For details concerning application procedures, please contact Rosalee Emory, (937) 255-5085x255, or <***http://www.gdp@asc.hpc.mil***>.

Participants

The following contacts represent the consortium participants from AFIT, ASC MSRC, and the AFRL. The list is organized by CTA area. The purpose of the TRIADS is to determine and coordinate appropriate computational curriculums and graduate research within each CTA. The Graduate Program Advisory Group is responsible for enhancing the multidisciplinary research opportunities as well as formally organizing the Graduate Program structure.As mentioned in the previous section, current information and enrollment assistance can be accessed through the PET Program Office at (937) 255-5085x225 or <***http://www.gdp@asc.hpc.mil***>.

CTA Triad Listings

Participation continues to evolve among the DAGSI Partners. Consult the WWWeb listings shown at end og theis section for updates.(Note: Telephone Prefixes 937-25x-xxxx)

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ASC/MSRC

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AFRL

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Computational Structural Mechanics (CSM)

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AFRL

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Computational Chemistry & Materials Science (CCM)

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AFRL

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Computational Electronics/Nano-Electronics (CEN)

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AFRL

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ASC/MSRC

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Ohio State University
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ROME Lab

Dr Richard Linderman
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Computational Electromagnetics and Acoustics (CEA)

AFIT/EN

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ASC/MSRC

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W W Web Addresses:

AFIT/EN - *http://www.afit.af.mil/Schools/EN*
ASC/MSRC - *http://www.asc.hpc.mil*